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Dr. Augustus Voelcker.

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LECTURE ON TOWN SEWAGE.

BY

DR. AUGUSTUS VOELCKER.

DELIVERED AT THE WEEKLY COUNCIL MEETING OF THE ROYAL AGRICULTURAL SOCIETY, MAY 28, 1862.

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ON TOWN SEWAGE.

It has been calculated that nearly 200,000,000 tons of liquid pass annually through the London sewers, containing an enormous quantity of excrementitious matters, of which the substances have been very carefully calculated both for the London sewers and also for other towns. I desire especially to refer to the excellent paper published some time ago by Mr. Lawes in the 'Society of Arts Journal,' which seems to me very conclusive. Mr. Lawes states, that the total amount of such matter, when deprived entirely of water, comes to 46 lbs. per head per annum, in which there are 35 lbs. of organic, and 11 lbs. of mineral substances. The principal, if not the sole, valuable fertilising matter in the organic substance is the nitrogen, which is found, partly as ammonia, or ammoniacal salts (chiefly carbonate of ammonia), and partly, to a minor extent, in the shape of organic matter in a state of incipient decomposition, in which state it readily contributes to fertility. The most valuable part of the mineral matter in the ashes is phosphoric acid, phosphate of lime, and potash, which enter into the composition of the urine. The nitrogen is by far the most valuable element of sewage. Mr. Lawes calculates the total quantity of nitrogen in the London sewage at 8859¾ tons, which corresponds to 10,758½ tons of ammonia; and the total amount of excrementitious matter, when perfectly dried, at 51,286¾ tons. We can thus arrive pretty well at a theoretical notion of the value of the sewage both of London and of other towns, and likewise of the average composition of sewage.

But the actual analyses of samples, taken at various times, perhaps afford us a still better criterion. Many of these have been published in Dr. Hoffman and Mr. Witt's report to the government; others in Mr. Mechi's pamphlet on the sewage of towns, as it affects British agriculture; the most recent analyses of London sewage, perhaps, are those which have been made by Dr. Letheby for the City of London. Taking the average of Dr. Letheby's analyses, I find that the total amount of solid matter in sewage taken from various main sewers comes to 94 grains per gallon during the day-time, and 79 grains during the night; giving an average for the whole day and night of 86 grains. But on putting together 24 of the analyses—25 were made altogether, but I reject one, because it contained an enormously large quantity of solid matter—taking 24 normal analyses of Dr. Letheby, and grouping them into two classes, the one showing less and the other more than 86 grains, I find in the former class 15 analyses furnishing on an average only 66 grains of solid matter in the imperial gallon, and in the other nine samples yielding on an average 123 grains. Now, considering that this occasional excess of solid matter takes place especially on rainy days, and is due

mainly to the washings of the streets, and therefore principally consists of useless earthy and organic sweepings, I think we obtain a wrong idea of the concentration of the sewage by striking an average in which we incorporate all the analyses made throughout a certain period of the year. If we rejected the abnormal results, we should arrive at a better idea of the average quantity of solid *fertilising* matter, which is our chief object. We should then find that the average proportion of solid matter, which is given by Dr. Hoffman and Mr. Witt as high as 102 grains in the imperial gallon, is too high, and that 70 grains per gallon, or one part in a thousand, is a fairer estimate than even the 86 grains, Dr. Letheby's average result.

This quantity agrees remarkably well with observations that have been made in other localities. Thus, in the sewage of Birmingham I find an average of nearly 70 grains; sometimes a little less, sometimes a little more. We must naturally expect such variations. Dr. Wrightson also found there about 70 grains; and in the sewage of other towns the average of solid matter is seldom much higher than 80 or 90 grains. Even in the most concentrated sewage of Birmingham the amount of solid matter is, as I know, seldom higher than 105 grains. On the whole, then, I believe we are not far wrong in stating that town sewage contains on an average one part of solid matter in a thousand.

Let us inquire, in the next place, into the character of the solid matter. Messrs. Hoffman and Witt estimated that the 102 grains which, according to them, are found in the imperial gallon, consist of—nitrogen 6·7; phosphoric acid, 1·8; potash, 1; organic matter, 30·7; or a total quantity of 40·2 grains of fertilising matter—the remaining 62 grains being worthless. Supposing a gallon of London sewage to contain 90 grains of solid matter—an over-estimate, which I take that I may be certain of dealing fairly with sewage—the following Table will fairly represent its composition:—

Average Composition of London Sewage.

	1 Gallon contains	1 Ton contains			1 Ton of the Dry Constituents of Sewage contains	
	Grains.	lbs.	ozs.	lbs.	lbs.	lbs.
Organic matter and salts of ammonia ..	30			1		747
Yielding ammonia .. .. 7 grains	..	0	3½		163¼	
Mineral matter	60			2		1493
Containing—						
Phosphoric acid .. 1 grain	..	0	0½		23	
Potash .. .. 3 grains	..	0	1½		69	
Worthless matters .. 56 grains	..	1	14		140	
Total amount of constituents ..	90			3		2240

I find then, in these 90 grains, 30 of organic matter (including 7 grains of ammonia) and 60 of mineral matter, and that in this mineral matter the valuable portion, the phosphoric acid, amounts

to 1 grain, and the potash to, at the maximum, 3 grains. In a ton of sewage we have 3½ lbs. of salts of ammonia, 2 of mineral matter, and in this mineral matter half an ounce of phosphoric acid, 1½ of potash, and nearly 2 lbs. of worthless matter. A ton of the dry constituents of sewage contains 163½ lbs. of ammonia, 23 lbs. of phosphoric acid, 69 lbs. of potash, and nearly two-thirds of it is worthless matter. So that, even if we evaporate sewage into a state of dryness, we should still have in the solid matter a very considerable portion of useless material. This point deserves special attention, for in valuations of the sewage of towns it is always compared with Peruvian guano. Now, if we leave the water out of consideration, it is hardly fair to compare the dry matter of the sewage with a material like guano, which hardly contains any valueless substance.

Let us now examine the value put upon sewage by various chemists. Professor Hoffman calculates that a ton of sewage is worth on an average about 2*d*., or 17*s*. 7*d*. per 100 tons. Accordingly the whole sewage of London would be worth 3796*l*. per diem, or the enormous sum of 1,385,540*l*. per annum. Guano at 11*l*. per ton is the standard on which these calculations are based. It is calculated how much ammonia occurs in the solid matter of sewage, and this is valued at 56*l*. a ton. The amount of phosphate of lime is calculated at 7*l*. a ton, and the potash at 31*l*. a ton; the result being that the total solid residue from sewage is thus valued, in round numbers, at 6*l*. per ton. Now, following the same track which other chemists have trodden, I find that, by taking the average composition which I here assume, the *solid matter* in London sewage would be worth about 5*l*. 2*s*. 4*d*. a ton. In this estimate I take ammonia at 6*d*. a lb., potash at 3*d*. a lb., and phosphoric acid at 2*d*. a lb. According to this estimate a ton of sewage would be worth not quite 1¾*d*.

These theoretical calculations, however, are altogether fallacious; for, in calculating the value of a manure, we must not merely estimate the amount of fertilising matter which it contains, but must consider its bulk and combination. The calculations on which comparisons are drawn between guano and sewage start on wrong premises. In guano we have a portable manure which we can supply when and where we want it, so as to supply an abundance of food to certain crops like our root crops at a critical stage of their existence. The same quantity of guano or superphosphate mixed up with a large body of soil—say 18 inches deep—would have been of little service for such an object. When once the roots are fairly established, with their various fibres drawing nourishment from the soil, and their leaves spread to the sun and air, and thus the apparatus for taking in food on all sides is formed, the natural sources of supply are amply sufficient to provide for their luxuriant growth. We cannot, in fact, materially alter the composition of our soils, taking the whole bulk of the soil into consideration, by any amount of manure. Nor can we chemically speaking, deteriorate the land by the most exhaustive crops, if we regard the soil as a whole. In reality we manure only

a small portion of the soil; and in ordinary good farm practice, we endeavour to keep the manure, be it natural or artificial, as near to the surface as possible. The value of a manure, then, depends quite as much on the facility with which it can be applied, as upon the amount of the fertilising materials which it contains. Concentrated manures, such as superphosphate of lime or guano, are, for this reason, of the greatest utility on most soils; for most soils are rich in plant food, but they do not contain sufficient to meet the requirements of the plant in its early stages of growth. Our ordinary farm routine is to manure principally a small portion of the soil, just to provide for this requirement.

On a sandy soil, it is true, we must put in everything that is to go afterwards into the plant; and it is on such soils that sewage may be used with very great advantage, and that bulky manures, like farmyard manures, will always be applied with as great, or even greater advantage than most artificial manures.

But on most other soils, and more especially those which contain a sufficient amount of clay, we have both a great abundance of minerals and also a considerable amount of matter capable of yielding ammonia in decomposition, as the following analyses show:—

Analyses of Three Clay Soils.

	I.	II.	III.
Water driven off at 212° F.	5·53	..	..
Organic matter and water of combination	3·62	5·38	6·11
Oxides of iron	3·07	6·82	8·34
Oxides of alumina		6·67	
Carbonate of lime	·74	..	..
Lime	..	1·44	·41
Magnesia	·60	·92	1·49
Potash	·26	1·48	·65
Soda	·22	1·08	
Phosphoric acid	·38	·51	..
Soluble silica	1·45	72·83	·04
Insoluble silicates (fine clay)	84·10		80·69
Chlorine and sulphuric acid	traces	traces	traces
Carbonic acid and loss	·03	2·87	2·27
	100·00	100·00	100·00

Moreover, clay itself possesses in a high degree the power of absorbing ammonia from the atmosphere. Still, however valuable may be the stores of food for plants which those soils contain, they do not appear to have enough in an available form for the young plant. We therefore apply a concentrated manure just to start the plant, and when this is accomplished, the manure has fulfilled its purpose, though it cannot add much to the general fertility of the land.

The maximum effect which such concentrated manure is capable of producing on a soil is soon reached. 3 cwt. of superphosphate of lime is found to answer quite as well as 6, 7, or 8 cwt. per acre,

The value, then, both of guano and superphosphate depends on their concentrated form.

If sewage had been compared with bulky farm-yard manure, instead of with guano, very different would have been the results. To illustrate this, let me point out the composition of fresh and of rotten farm-yard manure. Without entering into minutiæ, I may state that a ton of rotten dung contains 8½ lbs. of soluble phosphate of lime. This, at the usual price taken by chemists, is worth 2*s.* Then it contains 10 lbs. of potash, worth 2*s.* 6*d.*; 16 lbs. of ammonia, worth 8*s.*; and 12½ lbs. of insoluble phosphate, worth 1*s.*; thus we arrive at 13*s.* 6*d.* as the *calculated* value of a ton of farm-yard manure. I need not say that this calculated value is far above that which we actually pay. 3*s.* per ton, or at the most 5*s.* per ton, is, I believe, the price generally given for farm-yard manure. Making the same calculations for fresh farm-yard manure, I find the following result. We have 6¼ lbs. of soluble phosphate of lime, worth 1*s.* 8*d.*; 8¼ lbs. of insoluble phosphate of lime, 8½*d.*; 12½ lbs. of potash, 3*s.* 1½*d.*; and 15 lbs. of ammonia, 7*s.* 6*d.*; or a total of 13*s.* We thus get a value for rotten manure of 6*d.* less per ton than for fresh; and in both cases assume the value of farm-yard manure to be two or three times as high as it is in reality. Now, in dealing with a manure still more bulky, still less under our control than farm-yard manure, I cannot see why we are not to take into consideration that its value in a great measure depends on its being manageable.

Sewage manure, then, is only valuable in special cases, such as that of land that has in itself little or no fertilising matter, but is porous, and allows certain crops to penetrate deep in search of food —that is to say, a sandy soil, such as those analysed in the following Table:—

ANALYSES OF FOUR SANDY SOILS.

	I.	II.	III.	IV.
Silica and quartz sand	96·000	92·014	90·221	94·70
Alumina	·500	2·652	2·106	1·60
Oxides of iron	2·000	3·192	3·951	2·00
Oxide of manganese	trace	·480	·960	..
Lime	·001	·243	·539	1·10
Magnesia	trace	·700	·730	trace
Potash	,,	·125	·066	} ·10
Soda	,,	·026	·010	
Phosphoric acid	,,	·078	·367	trace
Sulphuric acid	,,	trace	trace	,,
Chlorine	[illegible]	,,	·01	..
Organic matter (humus)	1·499	·490	1·04	·50
	100·000	100·000	100·000	100·00

You will notice that the preponderating element in these sandy soils is silica. In some of them there is hardly any potash and phosphoric acid, and in two only a small quantity of phosphoric acid. These soils, then, are greatly deficient in every description of food.

Hence, if we want to get any crop at all, we must apply a bulky manure and an abundant supply of food. Now sewage is well calculated to furnish this food, provided we apply it largely, and not, as has been proposed, in quantities amounting to 3000 or 4000 tons per acre. Those who recommend such a small quantity forget that in 300 tons of London sewage we have in reality not more than the fæces of five persons—a supply for which it never can be worth while to lay down pipes or to make any provision whatever. I hold with the most ardent advocate of the use of sewage, that it is a pity that a liquid which contains an enormous quantity of fertilising matter, and which may be used with very great advantage on sandy soils, should be let run to waste. Yet, if we wish to derive any material benefit from it, we must use it largely—that is to say, as ordinary water is used for irrigation, in quantities amounting to from 8000 to 10,000 tons per acre, in, say, five dressings, averaging 1400 tons apiece. But even then it will not benefit every description of crop, but, as has been proposed, may well be restricted to Italian ryegrass and other grass-crops.

Grass is especially benefited by the sewage of towns, because it is a quick-growing crop, which allows us to apply a fresh fertilising matter as soon as a given quantity is exhausted. Grass-land may be manured repeatedly, but not so the cereal crops. Our wheat would never ripen if, after it has passed through its grassy stage and approached maturity, we were to apply sewage to it: the grain would never get formed. Neither is sewage generally applicable to market produce; it has a tendency to encrust the soil and to close up its pores, which is a great practical inconvenience. But apart from this objection, I question whether we could dispose of the sewage of a large town in market gardens, because it must be dealt with at all times of the year, and in very large quantities.

With regard to the grass grown by the application of sewage, it is stated in many treatises that the produce from irrigated meadows, more especially meadows irrigated by sewage manure, is superior, inasmuch as it is richer in nitrogenous matter than ordinary farm produce; but I believe that this is a mistake, and that in nutritive quality the grass from the irrigated meadow will be found inferior to that from natural pastures, the produce of meadows irrigated by sewage being in a still higher degree inferior. In fact, the more rapidly produce is grown the less mature it is, and the more likely to produce disorders in the animal economy; whilst, bulk for bulk, the poorer the meadow the more scanty the herbage, and the more slowly it grows, the better and more nutritious it is. Of course it does not follow that we should leave off manuring our fields and grow a scanty increase for fear of inferior produce.

Notwithstanding all these drawbacks, however, great sums have been realised by the application of large quantities of sewage to meadow land. And, after all, the most satisfactory way of arriving at a fair and just estimate of the value of sewage is to inquire of

men who have tried it on a pretty extensive scale. We learn from farmers residing in the neighbourhood of Edinburgh that they can realise by the application of sewage from 25*l.* to 40*l.* per acre—the average perhaps is about 25*l.* per acre. But if we calculate the value of the dressings applied, as has been done by Dr. Hoffman and other chemists, and, *for illustration' sake,* by me to-day, we shall find that the calculated value of the fertilising constituents comes to something like 75*l.* or 80*l.*, whilst the profit realised is only 25*l.*; which shows plainly the exaggerated nature of these calculations. If we look rather to the produce than to the price set upon the constituents of sewage, it will be found that its fertilising value is on an average perhaps one halfpenny a ton.

Moreover we learn from the practical experience of men who apply the sewage under the most favourable circumstances that the produce rises just in proportion to the quantity applied. To get a material advantage from the application of sewage it should go through the soil. Those soils will be most benefited by its use which act merely as the vehicles for holding the manure. We must never think of storing up the liquid manure in the soil. The soil does not hold such fertilising matters.

A great deal has been said of the powers of soils to absorb manuring matters; and it is true that all soils, not even the most sandy soils excepted, have the power of rendering insoluble to a great extent the soluble fertilising matters that we usually find in manures; but they have not the power of rendering them *completely* insoluble, and from very dilute liquids they take away very little indeed. If time permitted, I could refer you to some experiments which I have made with a view of ascertaining whether soils have the power of retaining soluble matters to any extent; but it may suffice to state in a general way that the weaker the solution the less is the soil capable of retaining the soluble matter. Thus, in operating with very dilute solution of ammonia, I find that hardly any ammonia is retained by the soil; and again, that the proportion of phosphoric acid which is left in the liquid after passing through the soil is just as large as it was before it was applied.

By filtering very dilute liquids, such as sewage, through soils which, like clay soils, contain potash, you may even take out the potash. This was the case with an experiment which I made on Mr. Mechi's soil. By filtering some of his tank liquid through his clay land I actually obtained more potash in the liquid that filtered through the soil than was contained in the tank liquid itself; thus showing plainly that the fertilising matters from very dilute liquids are not retained in the soil; and that we must not, therefore, calculate upon storing in the land during winter the fertilising matters of sewage. If we are to derive benefit from the practical application of the sewage of towns, we must apply it in large quantities, and get an immediate return in the course of four, five, or six weeks. Then we may give a new dose of manure with advantage, and so on. But with so dilute a liquid, which absolutely contains a considerable amount of fertilising mat-

ter, but relatively a small quantity, we can follow this procedure to advantage only with grass-crops.

It may be said that liquid manure has also been used with advantage on clay soils. To this I would reply that on clay soils, when well drained, pure water has been likewise used with very great advantage; and that by irrigating clay soil with the purest water, even distilled water, we should probably obtain a very high produce. Indeed, experience shows that in our neighbourhood, where clay soils,—well-drained clay soils, abound, the spring produce is almost entirely regulated by the amount of rain that falls. A showery spring gives us more grass than any description of manure, be it natural or artificial, that we can put upon the land. When, therefore, sewage produces on clay soils a highly beneficial effect, I think it is principally in virtue of the amount of water which it supplies.

Mr. Mechi made a true observation when he said that in all calculations the water has been neglected. In many cases it is a most valuable constituent. In the case of clay soils which contain an abundance of fertilising materials, the water, when put on in large quantities, so as to soak completely a large mass of soil, renders these materials soluble, and by degrees they are brought within reach of the growing plant. Thus it is that water, pure water, on clay soils produces in many cases enormously large results. In such cases the quantity of matter which we put on in sewage is too small to have any practical bearing on the result. Whilst, then, on clay soils water is the most valuable constituent of sewage, it is also of great utility on sandy soils, although, when we must furnish to the soil all the plant food required to produce a crop, even the fertilisers contained in sewage assume a very high importance. There are various other topics on which I must not touch, after having already detained you so long, but I trust that on several points which I have brought forward to-day I may have removed some misconceptions affecting that important question, the proper application of town sewage.

Sir John Johnstone, M.P., observed that he, with some other gentlemen, had superintended a large lunatic asylum in the neighbourhood of York, and had endeavoured to utilise its sewage in various ways. Not having grass-land sufficient to take it all, they had poured a part over the garden ground cultivated by the patients, in the hope that what was valuable in it might remain in the soil. It was so applied during the winter, and the governor of the institution fancied he saw good results in the crops of roots, cabbages, and other market-garden produce; but after what the learned professor had stated to-day it seemed to be doubtful whether it might not as well be let run into the river. The soil was diluvial, and of a rather porous sandy nature.

Mr. Frere said Dr. Voelcker had showed that the value of a fertiliser might be estimated by the crop that it enabled us to grow off the soil. Now it must be borne in mind that certain fertilisers

were of the nature of stimulants; so far, therefore, as their virtue was a stimulating virtue, which induced the soil to part with more of its plant-food than it would otherwise do, so far it would leave the field in a poorer condition than it found it. So that some charge must be made against the crop for impoverishing the field. No doubt, *if* we are justified in believing that the soil of a field has a standard fertility which could be but little changed either by the application of manure or by exhausting crops, so far the deteriorating influence of stimulating manures might be overlooked.

Mr. Blackburn said, as to the difference in value of different crops of grass, he had believed that plants, including grass, which grew quickest, contained the largest amount of sugar and starchy matter, and that, from slowness of growth, the sugar and starchy matters became converted into woody fibre. He found, for example, that the quicker his garden crops, celery and other vegetables, grew, the better was their quality. He believed that Professor Way supported that view.

Dr. Voelcker said, it was at one time generally believed that the amount of nitrogenous matter was the measure of the nutritive quality of the produce, and Professor Way, with other chemists, having found in the grass and hay of irrigated meadows more nitrogenous matter than in ordinary produce, arrived at the conclusion that it was really more nutritious. But now the tide has set in a different and more reasonable direction—a direction that is borne out by practical experience. Now an excessive quantity of nitrogen in produce is regarded rather as an indication of unripeness, of which one defect is a deficiency of sugar. If in young produce there is not so much woody fibre as in old, there is not so much sugar. If the produce be allowed to get over-ripe the sugar becomes converted into cellular fibre; but to a certain extent both went on being formed together. In young celery there is one thing in much larger quantity than in old, that is water. Indeed, in all forced produce, the quicker the growth the more water you have. The crisp condition of celery is in a great measure due to the large proportion of water present, which comes to 93 or 94 per cent.

In reply to an inquiry by Mr. Raymond Barker, Dr. Voelcker said that hay could not be made on irrigated meadows at all. He had stated that irrigated meadow-land did not yield so nutritious a produce as natural pastures; he might go further and affirm generally of all kinds of produce, that just in whatever degree an abundance of manure was applied and larger crops were obtained, in that degree would the quality of the crops be inferior. The rule holds good for wheat and barley, and even turnips. If you want something good, you must be content with a small quantity; if you want much, you must take it in a cruder state. If you want a good leg of mutton, for example, you must be content with a small one, and kill a Southdown sheep; if you want a large one, you will kill a Cotswold, and get coarser meat.

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